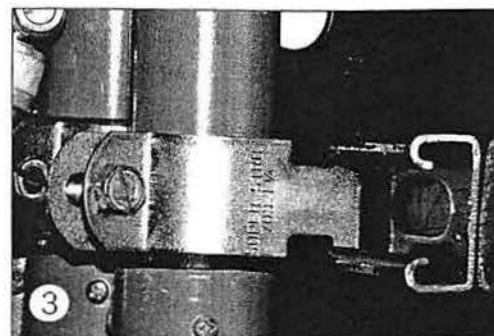
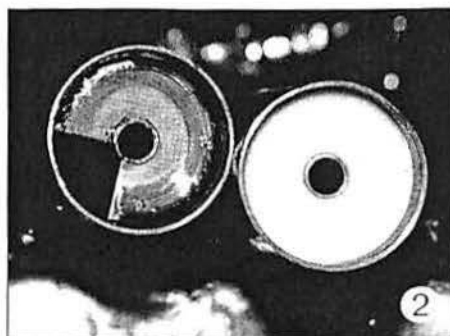
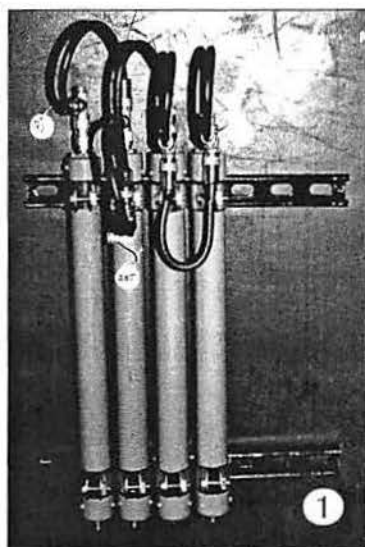
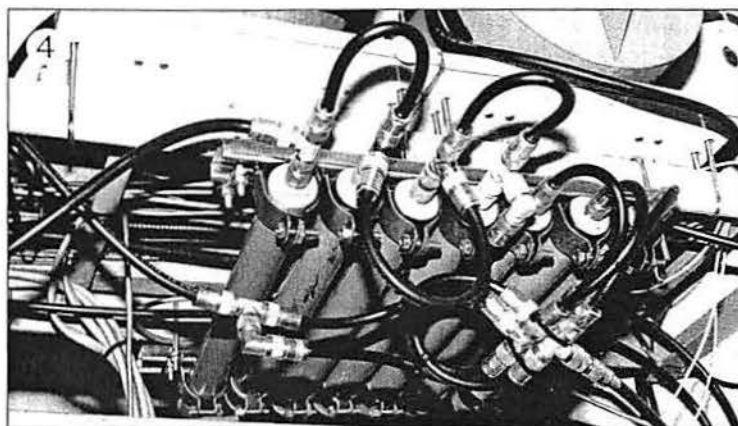
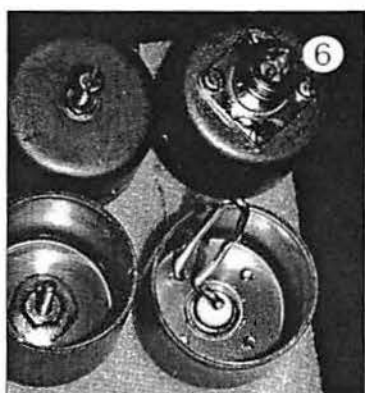




Custom-fabricated VHF cavity filters. Clockwise: (1) a cavity duplexer arrangement; (2) link side and tuning side of cavity [center insulator for $\frac{3}{8}$ -inch pipe not installed]; (3) pipe strap attachment on strut channel; (4) three-way duplexer [three transceivers connected to one antenna]; (5) assembled cavity with black shrink tube; (6) both sides of pipe caps, link and tuning.



Make VHF cavities from over-the-counter hardware

Fabricating simple cavities may seem like work, but space, cost, flexibility and ease of tuning make the concept an attractive alternative.

By Patrick E. Buller

Often a situation arises where an expensive VHF cavity is not only big and bulky, but it also can result in more insertion loss than necessary. An economical approach is to fabricate smaller cavities from readily available materials. The experience can be rewarding and recreational.

The operation of most VHF-UHF cavities is based on the *quarterwave*

Buller is an electronics design engineer for the Washington State Patrol, Bellevue, WA. He is also a member of IEEE, NARTE, RCA, APCO, ARRL.

theory, where one end of a conductor is grounded, leaving the other end at a high-impedance (voltage) point. Minimum insertion loss is one of the goals for both *notch* and *pass* cavities. Notch and pass cavities differ only in the manner in which energy is inserted and removed. Pass cavities have two connections, one for the insertion of power, and the other to remove power at the tuned frequency. The pass cavity, when used as a notch cavity, will have one unused loop or port. A pass cavity can simultaneously operate as a notch cavity if its loop is tuned with a capacitor to a notch frequency and the pass cavity

is left tuned to the pass frequency. Notch cavities have one coaxial connection to remove energy at the tuned frequency. This discussion will be limited to the notch feature. Using large (4- to 10-inch) pass cavities for notch applications is an excellent approach, but it's overkill for wide frequency separation.

Q value

The term "Q" is a dimensionless value defining a "quality of merit" of tuned circuits. For a cavity, Q is a measurement of its narrow bandwidth of either pass or notch capabilities. A value of Q_u (unloaded Q) is directly



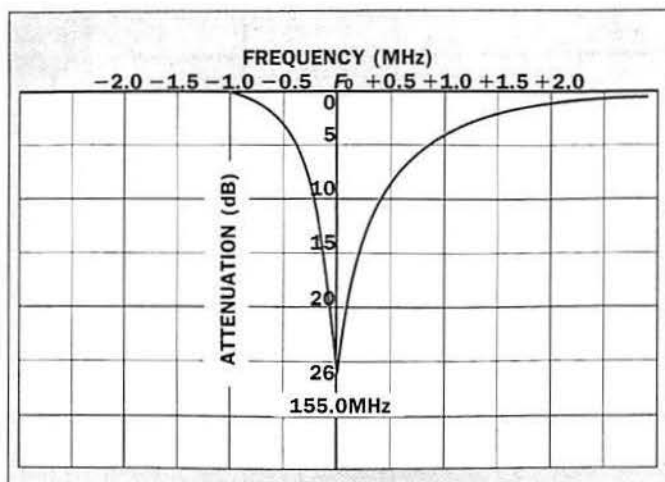


Figure 2. Decibel attenuation vs. frequency of a single-pipe cavity directly connected with a coaxial "T." The shape of the notch is that of a low-pass filter.

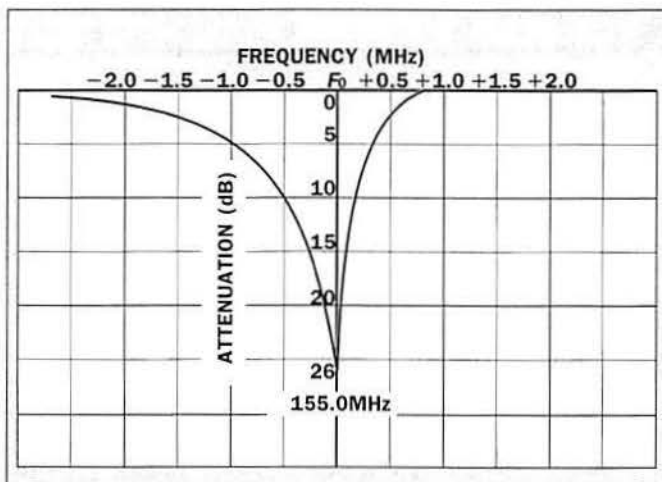


Figure 3. Decibel attenuation vs. frequency of a single-pipe cavity connected with a quarterwave stub, shifting the response to that of a high-pass cavity.

proportional to its volume. The larger the volume, the higher the Q . It is also influenced by the amount of coupling, called the "loaded Q ," (Q_L). The relationship between selectivity (3dB bandwidth) and Q is demonstrated in the equation

$$Q = F_0 \div BW$$

where F_0 is the center frequency and BW is bandwidth.

As the Q is increased, the bandwidth decreases, or sharpens, the frequency

response. Increasing Q for more selectivity, the insertion loss increases, as determined by the equation

$$L = 20 \log_{10}(1 + (Q_U \div Q_L)).$$

For a bandpass cavity, Q_U and Q_L are transposed.

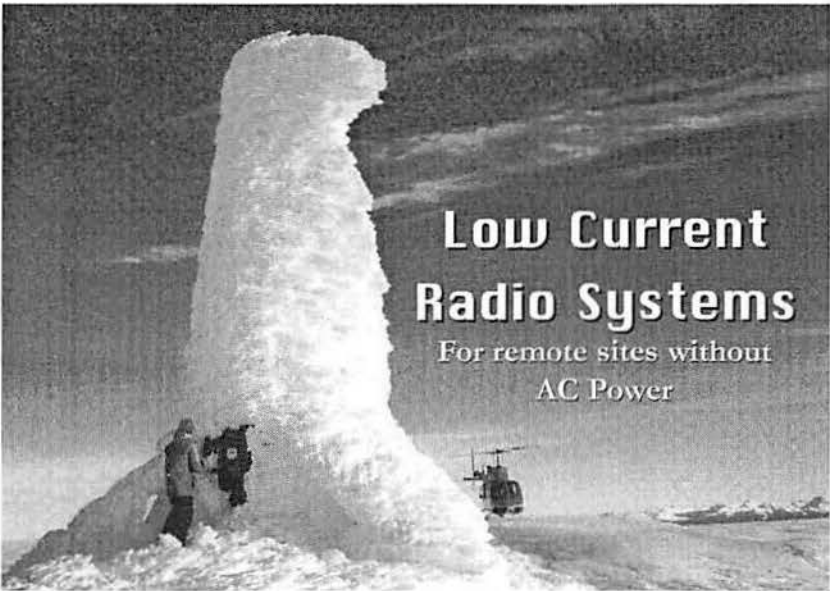
Values of Q range from 2 to 5 for broadband applications, such as a quarterwave coaxial cable, to that of a crystal having Q values beyond 10,000. The average Q for a 10-inch diameter

VHF cavity is about 350.

For coaxial cable use, cavities use *coupling loops*, usually identified by the insertion loss (i.e., 0.5dB, 1dB or 3 dB). The 0.5dB loop reduces the Q factor more than the 3dB loop. Another way of stating it is that a 0.5dB loop loads the cavity much heavier than the 3dB loop. Operating a cavity at $3/4$ -wavelength provides a higher value of Q , but it is generally not economical.

The assembly drawing shown in Figure 1 on pages 34 and 35 shows the design and construction of a cavity that has been in service for more than 15 years without failure. It was fabricated from 17.5 inches of 1.5-inch-diameter copper pipe. The only drawback is its temperature tolerance. The cavity is not recommended for applications where the ambient temperature will swing from -30°F to $+120^\circ\text{F}$. However, it is well-suited if the building can be maintained between 50°F and 90°F . If a reasonable temperature environment can be maintained, this may be just the thing for you. This design evolved because of the ease of repair and construction from readily available materials found in well-stocked hardware stores or at refrigeration-supply specialty stores. Coaxial connection to the cavity can be made with either type N or the common SO239 connectors. Test results show the "N" fittings are superior when three or more cavities are connected in any fashion.

The area of the loop (area between conductors) determines the amount of cavity coupling. Squeezing the loop conductors together decreases the total loop area, thereby reducing coupling, while increasing the loop conductor spacing increases coupling, which increases attenuation. The photographs of selected components on page 32 show the final form.



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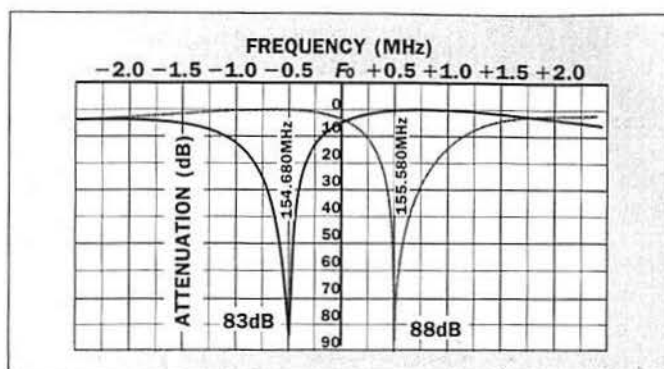
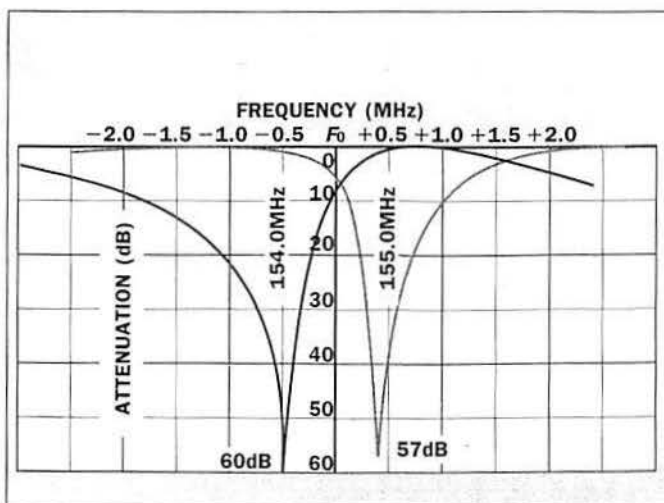


Figure 4. (Left) Decibel attenuation vs. frequency of a four-cavity assembly tuned at 1.0MHz spacing, with each cavity adjusted to 26dB of notch.

Figure 5. (Above) Attenuation vs. frequency of a six-cavity system at 900kHz spacing, with each cavity adjusted to 24dB of notch.

Initial adjustment

Each cavity should be individually adjusted to about 25dB if the frequency separation is 900kHz or more and to 20dB if approaching 800kHz spacing. Increasing the loop area will not only increase the notch attenuation but also the insertion loss close to the notch frequency. A spectrum analyzer with a tracking generator should be used as a tuning aid to display the notch while changes to the coupling are made.

Figure 2 on page 36 shows the frequency response of a single cavity

connected directly by a coaxial "T." Note that the shape of the notch is that of a low-pass notch filter. Adding a quarterwave coax from the "T" to the same cavity shifts the response to that of a high-pass cavity, as shown in Figure 3 on page 36. One-eighth-wave cable attached to the cavity makes the response uniform on either side of the resonance.

Three cavities interconnected with quarterwave cables will result in a nominal low-pass notch of 80dB. Three cavities, each having a quarterwave stub, and interconnected with quarterwave cables,

gives a high-pass notch of 85dB. Connecting each notch filter to a common point with another quarterwave cable yields a *cross-notch duplexer*. Figure 4 above shows the response of four cavities interconnected in this fashion and tuned at 1.0MHz spacing. In this case, each cavity was adjusted to 26dB of notch. Figure 5 above shows the response of a six-cavity arrangement, with each cavity adjusted to 24dB.

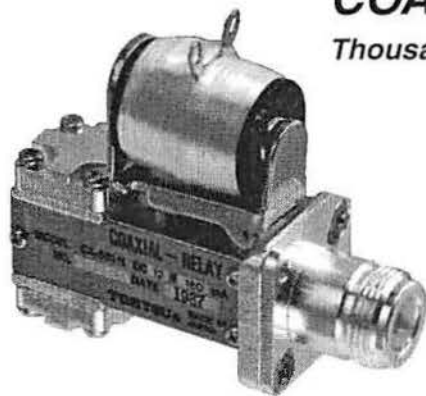
Filtering

One application for a notch cavity is the attenuation of an offending 155MHz transmitter generating noise on a receiver tuned 800kHz above or below the transmitted frequency. Adding a one-, two- or three-cavity assembly on the output of the transmitter reduces the offending noise with minimal attenuation to the transmitted signal. Where available space is a concern, this assembly can be mounted inside the base station cabinet. Installations are in service, using this design, that couple many receivers to one line with less than 0.25dB insertion loss. The common method of connecting two receivers, with an impedance-matching harness, nets about 3dB power loss. Another useful application is combining two 100W simplex base stations to one antenna. The spacing is 900kHz, and insertion loss is 1.25dB, resulting in 87W from each transmitter going to the antenna, as shown in Figure 5.

These cavities are most economical where the spacing between channels is greater than 800kHz. Anything closer than 800kHz with insertion loss less than 2.0dB requires a cavity Q greater than is possible with 1.5-inch-diameter pipe.

Mounting and cabling

The most economical method of mounting these cavities is to use the



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pipe-support systems developed for electrical conduit, often known by the trade names Unistrut or Superstrut. The pipe straps do not affect the tuning when fully tightened. Heat-shrink tubing of sufficient length is placed around the 1.5-inch copper tubing to isolate the copper metal from the steel mounting hardware. This prevents the dissimilar metal electrolysis from taking place. A benefit of the mounting scheme is that the entire coax and cavity is dc-isolated from the mounting assembly, which prevents unwanted ground loops.

Always use double-shielded or solid

outer-shield cable to interconnect cavities and also to connect to the equipment and antenna. Single-shield cable, such as RG8/U or RG58/U, has too much leakage and prevents maximum attenuation. It is also a source of extraneous radiation.

Success stories: Interference

The Washington State Patrol (WSP) was receiving severe interference on 155.580MHz from another transmitter on 154.740MHz located several hundred feet away in another public safety building. The WSP receiver desense

measured 35dB. A two-pipe cavity (40dB attenuation) was installed on the offending transmitter's transmission line, which eliminated the desense. The transmitting power output was 95W without the filter and 93W (0.09dB loss) after the filter was installed. Both parties are pleased with the results.

Another case involved the National Weather Service (NWS) transmitter at 162.550MHz, U.S. Customs at 165.2375MHz and WSP's repeater transmitter on 155.580MHz mixing, which created interference to WSP's repeater input. A four-pipe cavity was installed on the repeater input with two cavities tuned to the U.S. Customs output frequency and the other two cavities tuned to the NWS frequency, which eliminated the problem.

In the third case, the FBI needed a remote receiver at one of WSP's communications site. The frequency separation was more than 7MHz, making the installation of a two-pipe cavity more attractive than the installation of another antenna for the FBI. The two-pipe cavity coupled the two receivers to the single antenna with only 0.20dB of insertion loss. The common approach of using 75Ω quarterwave cables and a coaxial "T" would have resulted in more than 3dB of loss.

Combining radios

The most useful application is combining several transmitter and receivers to one antenna. Having separate antennas for each transmitter often generates problems in fringe areas. A mobile unit will find a hot spot for two-way communication on a given channel, but when the unit moves to another channel, communication is lost if the antenna is on the other side of the tower or, worse yet, if the antenna is much lower on the tower than the antenna used for the initial contact channel. Combining both radios to the same antenna provides identical communication capabilities. In other words, the hot spot is the same for both channels. An added benefit to this application is fewer antennas required on the tower. As many as four transceivers can be coupled on one antenna with these pipe cavities.

Maintenance

If the insulator inside the 3/8-inch pipe fails because of a voltage breakdown, it can easily be replaced. Remove both end caps and insert a rod inside the 3/8-inch pipe to force the Teflon insulator out. Insert a new insulator from the tuning side of the cavity. ■

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